1. The formation of the resins from the simple aldehydes.

2. The formation of the resins from the complex aldehydes or carbohydrates.

3. The formation of the resins from the terpenes.

It is not impossible that the resins are formed by any one of the above syntheses. There are abundant reasons for believing, however, that the synthesis of many of the resins is intimately related to the terpenes, that is, the terpenes may be first formed from simple compounds as the hemiterpenes, then converted into the resins by condensation and oxidation. This reaction seems entirely in accord with the chemical changes which naturally take place as phytochemical changes usually proceed from the simple to the more complex, as for example, from formaldehyde to the carbohydrates, but never from the carbohydrates to formaldehyde.

From the study of these terpene derivatives, it seems more than probable that the resins, at least those on the pine family, bear the same general relationship to the terpenes that naphthalene does to benzene and that the terpene molecule, $C_{10}H_{16}$, is the common substance from which the resins are derived.

G. B. FRANKFORTER
UNIVERSITY OF MINNESOTA

THE METAPHOR IN SCIENCE

THERE are several examples in the history of science where an idea at first represented by some metaphorical expression became in course of time a concrete existence. Most of the sciences have instances of it; one meets first with a notion, often of the vaguest, a principle, a property, a potentiality for something or other, and one ends with a substance, a species of matter, tangible and ponderable: the notion has become incarnated.

Inorganic chemistry offers us an excellent case of this sort of thing. When Lavoisier was working out the character of the substance we now know as oxygen, he had not isolated oxygen by a stroke of genius and then proceeded to study the properties of the new chemical product; the history of its discovery was far otherwise. Acting on some hints given him in October, 1774, by Joseph Priestley, Lavoisier came upon what he soon named as the "principle of acids" or "the acidifying principle"; his words are (1777):

> I shall therefore designate dephlogisticated air, air eminently respirable, when in a state of combination or fixedness by the name of acidifying principle or if one prefers the same meaning in a Greek dress by that of *oxygine principle.*

Here it is a principle, something which combines with metals when they are calcined or burned in air; it is that something which to Lavoisier seemed essential in acids, that which produced acidity, the oxygine principle. In its later and more familiar form of oxygen, it is better etymologically. That which was a principle in 1777 was about 120 years afterwards a visible, tangible entity—the liquefied, steel-blue oxygen gas. The principle of 1777 by 1897 had become a substance; the metaphor had become an actuality.

Not all chemical concepts have been equally fortunate in leading to true and individual chemical substances: phlogiston, for instance, denoting, as it did, no reality, is the conception phlogiston still. The principle of heat, phlogiston, was supposed to leave a body when it was burned: the theory of Stahl asserted that heat was a thing, a thing which could depart from a body and leave it lighter than before when it was cold. Now this, as a conception, is sufficiently definite, but as it is not true in fact, phlogiston never materialized; it was never isolated from matter because it never existed in matter. Phlogiston was as barren a conception as "oxygine" was pregnant. To-day Priestley and Lavoisier could be presented with an ounce or so of the "oxygine" principle, but not a milligram of phlogiston could be extracted for Stahl, for oxygen is a substance, but heat is a mode of motion. Probably the most pregnant metaphor ever used in science was Harvey's as

regards the movement of the blood—"motion as it were in a circle." This phrase was of course written in Latin as "an motionem quandam quasi in circulo haberet"; it forms part of the sentence thus translated:

I began to think whether there might not be motion (or a movement), as it were, in a circle. Now this I afterwards found to be true.

Later in the same chapter (VIII. of the "De Motu") he writes:

This motion we may be allowed to call circular (Quem motum circularem eo pacto nominare licet.)

The establishing of the fact of the circulation of the blood was absolutely essential to the creation of physiology; modern physiology has, indeed, arisen from this one fact, and the fact received its name—circulation—from the well-chosen phrase "circular motion." The phrases "circle" and "circular" of 1628 became in due time part of the language of physiology; and the circulation of the blood which was a phrase and an inference in 1628 became a visible demonstration in 1660. For it is a fact, one of the most pathetic facts in the history of biology, that Harvey died without ever having seen the blood moving as he knew so well it did, for he died in 1657, three years before Marcellus Malpighius—the man born in the year the "De Motu" was, 1628—saw the blood of the living capillaries of the transparent lung of the frog. Thirty-two years separated the metaphor from the demonstration, the prophecy from the fulfilment. Had Harvey lived three years longer, he could have seen with his own eyes that what he had prophesied was correct, he could have been shown as an actuality what his reason had discovered as a magnificent inference, the most magnificent inference ever made in the realm of the living.

The next example we may take from physiological chemistry and from that new department of it called "internal secretion." Until comparatively recently, the function of the two small yellow bodies situated near or on the kidneys—adrenals or suprarenals—was entirely unknown and barely even speculated upon. In 1855 Dr. Addison, of Guy's Hospital, London, described a disease, since named after him, in which the patient suffered from extreme weakness both of muscles and of heart, and after death was found to have had his suprarenal bodies degenerated usually through a tubercular lesion. Physiologists very properly assumed that the explanation of this was that in health the suprarenal bodies produced something which, gaining access to the blood, was carried to all parts of the body and maintained the efficiency or tone of the body-muscles and those of the heart and blood-vessels as well. This something was apparently absent from the blood in Addison's disease. This something remained undiscovered until 1895, when watery extracts of the suprarenals were made and injected into the veins of a living animal. The result of this was a surprising increase in the tone of the animal's heart and small arteries so that its blood-pressure rose greatly. Something was clearly contained in the suprarenal extract which had powerful physiological effects: let it be called "adrenalin." But it is one thing to name a hypothetical substance and another thing to isolate a real one. In this case, however, the hypothetical substance was a real one, so that after some years of work between 1897 and 1904, the physiological chemists succeeded in separating from the glands a substance in a state of purity which had all the properties possessed by an extract of the suprarenals. Adrenalin was for the first time isolated about forty-five years after its existence had been surmised. So perfectly had the chemical something that maintains the tone of heart and blood-vessels been isolated, that its constitution became so well known that the final triumph of making adrenalin synthetically was not long delayed. In 1904 it was made synthetically in Germany, and in the following year in England, so that within fifty years of its suspected existence, adrenalin, with all the properties of the natural material, was seen and handled as a pure, crystalline chemical substance of composition so well known that its structural formula could be written and a name denoting it laid before those capable of understanding it (di-oxyphenol-methyl-amino-

ethanol). Here we have literally the materialization of a chemical idea, the crystallization of a notion; the thing of the mind has become a thing of the laboratory, the thought has been captured and bottled.

The next "as it were" we shall take from the history of the physiology of the central nervous system in the writings of a pupil of Harvey, Dr. Thomas Willis. At the present day the name and the process "reflex action" is as well established as is anything in animal behavior. One of the most certain things in the physiology of the nervous system is that if we stimulate a nerve going into it, we shall produce outgoing effects, muscular contractions, vascular or glandular changes. If we decapitate a frog and hang up the body and apply a piece of acid paper to one flank, the leg of that side will be brought up to flick it off, and if the acid be very strong the whole frog will be thrown into convulsions—these movements are reflex actions. Now this very definite physiological conception of a reflex neural action arose in a metaphor, in an "as it were" of Willis penned about 1650. He said:

> We may admit that the impression of an object driving the animal spirits inwards and modifying them in a certain peculiar manner, gives rise to sensation and that the same animal spirits, in that they rebound from within outwards in a reflected wave as it were, call forth local movements.

Willis's notion was that of a wave reflected back towards its source, but the metaphor about nerve impulses being reflected evidently represented the truth, for it has lived on and become an integral part of the terminology of neural activity. If there had been no germ of accurate description in it, the idea contained in the metaphorical phrase "as it were reflected," would not have survived to our own day; but it has lived to become the definite description of a fundamental neural truth.

Dr. Marshall Hall, who did so much for the physiology of this sort of action, adopted the phrase and incorporated it in one of his own—the "reflex nerve-arc" which denotes the anatomical path over which reflected nerve-impulses travel. If Willis could visit our laboratories to-day, we could show him reflex actions performed with automatic precision, and below the microscope we could let him see the various links in a reflex nerve-arc. He would find his "as it were reflected" no longer taken in a metaphorical sense, but used as the most appropriate mode of denoting one of the commonest and most important of neural activities.

The study of nerve-impulses gives us another example of the inevitable tendency towards concreteness and definiteness in notions regarding the behavior of the central nervous system. If we go sufficiently far back, we find the Greeks, for instance, imagining that the nerve fibers conveyed spirits through their pores (poroi). No doubt these spirits of antiquity are the synonym of our "nerve-impulses," something propagated with considerable rapidity from one end of a nerve to the other. Still for ages that something was quite unapproachable on the part of the senses. Some physiologists imagined that the muscles became active because the spirits of the nerves rushed into them, but Borelli (1670) on cutting open living muscles under water could see no bubbling of gas or anything else suggesting them to be inflated with any kind of substance—spirit, flatus, succus nerveus or gas. But it is to his credit that Borelli looked for something of the kind; he desired to render the succus nerveus concrete, to see the action of the spirits in the nerves, if possible. It was not to be; for nerve-impulses are a mode of motion and only to be discovered through their effects. In our own day, one evidence of their passage along nerves, namely, the electrical, has been made sufficiently obvious by that exquisite instrument the galvanometer. By the aid of this very delicate apparatus, the electric currents produced by the nerve impulses can be made to swing a mirror reflecting a beam of light on to a screen, it may be, several feet away. Although nerve-impulses are no more visible to-day than were the nerve spirits of the Greeks or was the succus nerveus of Borelli, we are in a position to show these thinkers of the past a spot of light jerked two or three feet to the right or left of its resting

position through the instrumentality of an electric current generated by a single nerve-impulse whose electromotive force is not greater than 0.015 of a volt. We have not rendered nerve impulses evident to sight, but we have measured the electromotive force of their electrical manifestations as accurately as we measure the rise of temperature caused by minute quantities of heat.

We need not be surprised to be told that it was universally believed that nerve-impulses traveled with incalculable speed, that a flash of thought and a flash of lightning were both prodigiously rapid. In 1850 Professor Helmholtz measured the velocity of the nerve-impulse, and ascertained it to be about 40 meters a second in the nerves of man. Thus the movements of the spirits, once thought so erratic, have been measured; the intangible is still intangible, but the immaterial has been found to be in material and as such to be as real as the material, neither more nor less so.

Of late years there has been a very distinct tendency towards concreteness in regard to ideas of nerve-force and its diminution in fatigue and in disease. At one time nerve-force seemed to be the special property of the quack and the charlatan, but the microscope which has solved so many problems for us has shed its light also on this most elusive subject. A substance has been discovered in the interior of nerve-cells which is found to accumulate as the cell rests and to be worn away the longer the cell has been active. The substance takes the form of minute granules or prisms called after their German discoverer the granules of Nissl. The nerve-cells innervating the wing muscles of a sparrow have been examined in the early morning before the bird has begun to fly about, and similar cells have been scrutinized in a wholly similar bird after a long day of activity; on comparing these two sets of cells under the microscope, the thing wherein they were found to differ was the quantity and appearance of the granules of Nissl. Since these granules tend to disappear when nerve cells are active, and to reconstitute themselves when nerve cells rest, they are evidently to be regarded as the physical basis of nerve energy, the local seat of the processes concerned in the output and in the restoration of nerve energy.

It is clear, then, that the granules of Nissl with the evolution of nerve energy and may be called the dynamogenic material which is widely distributed throughout the nervous system. But it follows from this that fatigue, in so far as it has a microscopical basis, will be denoted by the more or less complete disintegration of the granules. Fatigue, which as understood by most people is merely a particular kind of feeling or sensation, has been shown to produce a cognizable change in some physical structure; in other words, it has been made concrete. General fatigue on its objective side has now been proved to be a condition of bodily poisoning. The prolonged activity of muscles and other tissues results in the output of certain chemical materials (fatigue-toxins) which, circulating in the blood, produce a mild poisoning, one of the effects of which is to depress the activity of the cells of the central nervous system, the objective sign of which is well known to be the partial solution of the granules of Nissl. Thus such comparatively indefinite and illusive things as nerve force and fatigue have by the microscopists and chemists of our time been identified and shown to have a local habitation and a general distribution respectively in the minute recesses of the living material of the body. The whole tendency here has been towards the objectifying of the subjective and the visibility of the unseen.

But of course it is very largely in the sphere of the healing art that this modern tendency towards concreteness is to be seen in its highest perfection. Let us take the case of malaria or ague, a disease the cause of which not so very long ago was absolutely unknown. Not that it was not attributed to causes such as "paludism," "telluric influences," exhalations, vapors, and so on, but these did not explain anything. The word malaria is of course derived from two Italian words meaning "bad air" clearly showing that the atmosphere was held to be responsible for some peculiar kind of corruption or infection as we

should now call it. Paludism, the influence of marshes, could not be seen; what could be seen were fogs or vapors rising from the marshy ground and these were blamed for spreading malaria, and people were told to beware of the damp and of night air. But why vapor, whether in the daytime or at night, should breed any kind of disease, most of all so definite a disease as ague, was not at all obvious. At last all these vaguenesses were dispelled, and malaria was discovered (1880) to belong to that already large group of diseases known as parasitic, only the parasite in this case was an animal and not a vegetable. Ague was found to be due to the destruction of the red blood-corpuscles by their having been made the residence of a minute animal parasite, the *Plasmodium malariæ*, which had been inoculated into the patient through his having been bitten by a particular kind of gnat or mosquito (*Anopheles*) which had sucked blood from some one suffering from malaria. It was not contagion, nor ordinary infection, far less bad air or vapors or exhalations, it was natural, accidental inoculation with foreign blood containing excessively minute living creatures classed by zoologists as a species of Protozoa.

Thus the connection of malaria with marshes and vapors and night-time was at once explained by the facts that the mosquito lays its eggs in damp places and frequents damp places towards evening and after dark. The meaning of the usefulness of quinine is explained by its being able to kill the parasite in the blood; it is only a local, circulating germicide. Thus the microscopist has tracked down one of mankind's subtlest foes, found it neither mist nor marsh, vapor nor corruption, but a moving, living creature, a member of the lowest group of such known. The vagueness has gone; the cause of malaria can be viewed sealed up in Canada balsam under a cover-glass.

Another excellent example of the rendering definite what was before of the vaguest is the recent discovery of the cause of plague, the pestilence, or Black Death. In the fourteenth century the great surgeon of Avignon, Guy de Chauliac, attributed the plague to a conjunction of the planets Saturn, Jupiter and Mars in the sign of Aquarius on the twenty-fourth of March, 1345. About the same time the Jews in Germany and Switzerland were suspected of poisoning the wells, and were in consequence persecuted and massacred. In the fourteenth century the medical faculty of the University of Paris was asked to deliver an opinion on the nature and origin of plague, but a very great deal that it promulgated was absolutely fatuous as regards protection or cure. One thing only was recommended that is interesting in the light of to-day, namely, the fumigation of houses by the burning of aromatic herbs and woods. Only as recently as 1894 was the vera causâ of the Black Death, one of mankind's most terrible traditions, discovered by two Japanese doctors, Yersin and Kitasato, and named the *Bacillus pestis*. It was soon isolated in pure cultures and grown in artificial media, and its toxins and antitoxins became chemical entities.

The history of the discovery of what plague is really due to is a strange, eventful history. The Black Death, that most dreadful scourge of mysterious origin, was for centuries attributed to such sources as the conjunction of planets, the iniquities of the Jews or to some special outpouring of divine wrath on account of human sin. Mankind, utterly at a loss to discover its true relationships, had for millennia imagined vain things, and essayed the most grotesque methods of averting it. But in the fullness of time the microscope was devised and with it the dawn of the day of exact knowledge had arrived.

The source of plague was shown to be a bacillus, a most minute, vegetable parasite which, growing in bodies of certain animals, rats and other rodents, could give rise to a most virulent poison (pestiferin) which was carried to all parts by the circulating blood. It was further shown that man became inoculated by fleas which had been feeding on the bacilli-containing blood of rats; and thus were revealed the several links in that long chain which had the *Bacillus pestis* at one end and man at the other. It took mankind 3,000

years to come to a knowledge of the truth regarding the cause and manner of spreading of plague, to a knowledge of that chain of cause and effect which connects microbe and man in the dire relationship of the plague-stricken.

Science, then, has come face to face with the specter of the Black Death and recognized its features. She has laid hold of "the pestilence that walketh in darkness" and made it reveal its horrid origin.

Similarly for influenza, a disease in its epidemic form, if not quite so deadly as plague, then quite as mysterious; in some forms quite as deadly. Very probably some of the great epidemics of the middle ages were in reality what we now call influenza, its very name being only the Italian for influence—a something inscrutable but omnipresent, mysterious in the last degree. The usual expressions were in vogue, it was a corruption in the air, a miasm, an exhalation and so on; until in 1892 the bacteriologist Pfeiffer isolated the organism of influenza and named it the *Bacillus Influenzæ*. Not the air, then, but the microscopic fungi it may hold for evil influence, is the true cause of influenza. The influence is now materialized, nay indeed is isolated and sealed down under glass for the inspection of trained eyes. Thus by the microscope are these deadly powers of the air one by one distinguished from each other and identified each in its particular malignancy.

No better example than that of the ferments could be given of a notion becoming in course of time a substance isolated and tangible. Fermentation, the totality of changes produced in digestible, coagulable or putrescible material, was for ages believed to be inscrutably mysterious. It was made the subject of debate between the iatro-mathematicians and the iatro-chemists of the seventeenth century, but neither school really understood it.

Digestion, the great fermentative process in animals, was confused not only with putrefaction, but with boiling and with the effervesence of gas in chemical operations. Stahl saw in digestion the direct activity of the soul or anima which, he held, permeated every tissue and endowed it with its special powers. The chemistry of it all, however, was unknown: the very conception of a ferment—a substance produced by living matter but not itself living—had not as yet emerged from the mental confusion.

Van Helmont (1577–1644), Sylvius (1614–1672), De Graaf (1641–1672), Haller (1708–1777), all groped for it, but it was not until through the work of Réne Antoine Ferchault de Réamur (1750) that any true idea was held as to the nature of fermentation in digestion. Réamur was the first to obtain gastric juice in an approximately pure state and to attempt digestion with it outside the body. Spallanzani, the distinguished Italian naturalist at Pavia, began where Réamur left off, and soon discovered that digestion was by no means putrefactive but was apparently due to some "solvent power" or "active principle of solution" in the gastric juice (1777). Then by degrees as physiological chemistry improved its methods, it got finer results, and at last "the solvent power" or "principle of solution" in the gastric juice was isolated in 1862 as the white powder, pepsin, a name which had been given to the active principle by Schwann as far back as 1836. Soon other ferments were either isolated or obtained in solution, and to-day in our laboratories we store in glass bottles half a dozen or more of the actual substances which are the modern representatives of the "principles of solution" of the early researchers. The vague has become definite, the conceptual power or property has become the material substance or entity.

The story of the discovery of the telescope, how it was bound up with that wonderful emancipation of the human spirit from the thraldom of mediæval ignorance and the hatred of scientific light, has been told us by many learned men; but I venture to think that the discovery of the microscope, which has never yet had its historian or poet, was one fraught with many more beneficent results for humanity. By its scrutiny the invisible but actual sources of most of the scourges of mankind have been discovered; and it would seem that it is in its power and not in that of fleets or

armies that we must look for the physical salvation of the sons of men. Man may redeem himself from death, not by sweeping the heavens with the space-annihilating telescope, but by peering into the dust of the earth with the space-creating microscope.

We see then that the principle of the incarnation of ideas, of the realization in the world of substance of what had been vaguely foreshadowed in the world of mind, is a process which has gone on in science as surely but perhaps not so conspicuously as it has in art. The artist succeeds more or less perfectly to incarnate his ideas of beauty in stone, in wood, in metal or in pigment, but no painter ever yet expressed all the loveliness in his mind, pellucid though his pigments were; the poet strives to give utterance to the majesty of his imagination, but no poet was ever yet satisfied that his words, choice though they were, portrayed all the delicacy of his fancy or the glory of his dreams. The musician is conscious that after he has swept the lyre with melodies of transcendent sweetness, there are unheard melodies that are sweeter still; the preacher whose eloquence stirs the vast cathedral returns home depressed in that his burning words did not rise to the fever-height of his fervor. The saint, aiming at the highest ideals of holiness, has still to confess failure whether as anchorite, prophet, missioner or philanthropist.

But it is sometimes given to the man of science to touch, to taste, to handle what was once only a notion, a suggestion, a forecast either in his own day or in that of a less fortunate predecessor in the earlier times of the history of a thought.

D. FRASER HARRIS

DALHOUSIE UNIVERSITY

A NEW FRENCH CAVERN WITH PALEOLITHIC MURAL ENGRAVINGS

To Count Begouen, of Toulouse, and his two sons, belongs the credit for the discovery of a new cavern with paleolithic mural engravings. The eldest son, Max, is at present a pupil of Professor Emile Cartailhac, as was his father before him. Count Begonen, with his family, is spending the summer at his country place, "Les Espas," at Montesquieu-Avantès, near St. Girons (Ariège). On property adjoining his is the cavern of Enlène known for many years and where the count himself recently discovered a finely carved spear-thrower of reindeer horn. Near Enlène the Volp, a small stream, disappears under a ridge of limestone and reappears about one kilometer farther down. The escarpment where the Volp reappears has long been known as the Tuc d'Audoubert. After improvising a small canoe made of a box and given stability by a float on either side—a keg and an oil can, on Saturday, July 20, Count Begouen and his sons ascended the channel for about 50 meters, as far as the present level of the water would permit of rowing. By bridging with ladders at intervals they ascended on foot much farther and then climbed to the entrance to a cavern on the left. This led to a series of large chambers remarkable for the quantity as well as beauty of the stalagmite and stalactite formations. Luckily these had not been despoiled by the hand of the tourist. Only two or three times did the party of four find evidence that they were not the first to behold these wonderful art products of nature. At one point a name with the date 1689; at another a name and the date 1701. After traversing a number of galleries they at last came to a small corridor near the end of which they saw a small pit which appeared to have been recently dug in a search for artifacts. The disappointment on finding the pit indicating that another archeologist had been there before was not of long duration, for on looking up they beheld simultaneously a number of animal forms delicately incised on the sloping walls, some of them surrounded by thick layers of stalagmite, others partially hid by the same. The figures include about half a dozen horses, nearly as many bison, one reindeer, one bovine animal and some ten curious signs, probably a weapon. One of the horses is represented as being caught in a trap, others as being struck by arrows. The figure of the reindeer